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ABSTRACT

A study investigated the known phenomenon of "intermediate effect" in which medical students with an intermediate amount of knowledge and experience demonstrate higher amounts of recall of the text of a medical case than either experienced clinicians or novices. In this study the amount of activation of prior knowledge was controlled by having subjects--24 fourth- and 24 sixth-year medical students at the University of Limburg (Netherlands) and 6 internists--spend either 30 seconds or 3.5 minutes recalling whatever they knew about endocarditis before being presented with an endocarditis case to comprehend and recall. Findings indicated that the more time subjects had available the more knowledge about the subject they were able to produce; that the amount of prior knowledge produced is a function of level of expertise (physicians produced more information than students); but that "experts" (physicians and sixth-year students) recalled less information but more relevant information about the case than did intermediates (fourth-year students). The results supported the theory that experienced physicians develop cognitive structures or "illness scripts" which they use to automatically represent a case. Contains 14 references. (DB)

Effects of Activation of Prior Knowledge on the Recall of a Clinical Case

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When medical students and physicians of different levels of expertise are requested to process a description of the complaints, signs and symptoms of a particular patient and to recall as much information from the text as they can, a characteristic inversely U-shaped curve emerges. Students at intermediate levels of expertise remember more information from text than both novices and experts. This phenomenon has been appropriately named the 'intermediate effect' in clinical case recall and has been demonstrated in many studies, under various conditions and with a multitude of experimental materials (e.g. Claessen, & Boshuizen, 1985; Hassebrock, Bullemer, & Johnson, 1988; Muzzin, Norman, Feightner, & Tugwell, 1983; Patel, & Medley-Mark, 1985).

Results as the ones referred to are quite counter intuitive. Research in the domain of text processing has generally shown that amount of recall simply is a linear function of prior knowledge: The more prior knowledge is available, the more will be remembered from a relevant text (Van Dijk, & Kintsch, 1986). Spilich, Vesonder, Chiesi and Voss (1979) for instance, found that subjects with high knowledge of baseball remembered more, and more relevant, information from a report of a baseball game than low-knowledge individuals.

Schmidt and Norman (1988) have suggested that the intermediate effect may result from the fact that physicians and intermediate level students operate upon different kind of knowledge structures and in a different way. Whereas medical students have to study a clinical case, consciously activating and processing causal pathophysiological knowledge typically available to them, experts process a clinical case in an automatic fashion, using what the authors call "illness scripts." These scripts contain relatively little pathophysiological knowledge (and mainly in compiled mode), but a wealth of clinically relevant information. They enable experts to rapidly recognize a case as a specimen of a particular disease and are the basis of their superior diagnostic performance. However, while processing a clinical case, they only remember information to the extent that it fits into the particular script applied. Hence, although physicians generally recall less; what they remember is more relevant to the case at hand (Boshuizen, 1988; Hassebrock, et al, 1988). These notions have several testable consequences. First, since intermediates quite arduously must activate and consciously process pathophysiological knowledge in order to understand the signs and symptoms presented to them, they may take more time than experts who just activate an appropriate script and fill in the slots. As a consequence, recall performances of intermediates is expected to be more sensitive to processing time constraints than expert recall performance. In

addition, if one would ask subjects after processing the case to explain the signs and symptoms in terms of underlying pathophysiological processes or mechanisms, one would expect intermediates to produce more elaborate protocols than physicians, because the latter have activated pathophysiological knowledge only in a compiled mode. In a study involving subjects of five different levels of expertise and three different processing time conditions, Schmidt, Boshuizen and Hobus (1988) corroborated these predictions. Intermediates produced more elaborate pathophysiology protocols and recalled more information than physicians when allowed to study a difficult endocarditis case for three and a half minutes, but when only 30 seconds were available for processing, their performance was poorer than the experts' performance. Moreover, the product-moment correlation coefficient between the number of propositions recalled and the number of propositions in the pathophysiology protocols was equal to . 51, suggesting that indeed the amount of prior knowledge mobilized for the comprehension task was responsible for the subjects' recall performance. Of course, these results merely suggest that the amount of processing of pathophysiological knowledge is responsible for the amount of recall, since no direct observation of processing was possible. The amount of processing of pathophysiological knowledge while studying the case was actually inferred from pathophysiology protocols acquired only after the processing of the case had taken place.

The present study was designed to remedy this shortcoming by actively controlling the amount of activation of prior knowledge. Subjects' prior knowledge was primed by having them recall whatever they knew about endocarditis for either 30 seconds or three and a half minutes, before requiring them to study the endocarditis case for 30 seconds. The expectation was that amount of recall of the criterion endocarditis case would be dependent on the amount of previous processing of relevant knowledge. Such finding would demonstrate that recall performance is indeed causally related to the amount of processing of pathophysiological knowledge, as was suggested by the Schmidt, et al (1988) study.

Since physicians are less dependent on conscious, elaborate processing of pathophysiological knowledge in order to comprehend and recall a case (simply because they operate upon illness scripts which encapsulate pathophysiological knowledge in compiled mode and which enable them to process a case in an automatic fashion), one would expect them to recall less as compared to students. This would be the case, even if one requires them to activate elaborate pathophysiologi-

cal knowledge, because this knowledge is not directly relevant to their performance. Such finding would support the notion that the intermediate effect in clinical case recall indeed results from the activation of elaborate causal, pathophysiological knowledge by students on intermediate levels of expertise.

METHOD

Subjects. Subjects were 48 medical students of the University of Limburg: 24 fourth- and 24 sixth-year undergraduate students. These groups were selected because in the previous study fourth-year students displayed the highest levels of recall whereas the sixth-year students recalled the case at the second year level, suggesting that changes in the prior knowledge applied to the case occur between the fourth (preclinical) and the sixth year. In addition, 9 internists participated in the experiment[1].

Material. The material consisted of a booklet containing a 270-words description of a clinical case and two blank response sheets. The case was a Dutch translation of the acute bacterial endocarditis case used by Patel & Groen (1986) and consisted of 71 propositions. It was identical to the one used in the Schmidt, et al. (1988) study.

Procedure. Each group was randomly assigned to one of two experimental conditions. They were given the opportunity to recall knowledge of endocarditis for either 3 minutes and 30 seconds (3' 30") or 30 seconds. Subjects were required to state everything that came to their mind in response to the experimenter's question: "Could you tell me everything you remember about the subject of endocarditis?" In order to check whether activation of prior knowledge took place in the way intended, the sessions were audio-taped. After completing the activation task, all subjects were requested to study the acute bacterial endocarditis case for 30"[2]. Subsequently, they were asked to write down whatever information they recalled from the case; to state a most likely diagnosis and to explain the signs and symptoms in terms of underlying pathophysiology.

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[1]As upon writing this paper, the analysis of data provided by 15 other internists are still in progress.

[2]Preceding the experiment, subjects were given the opportunity to read an unrelated text of exactly the same length to provide them with some experience in scanning a text in a very short time. This was done in order to minimize variability in the way subjects would undertake the experimental task.

Subjects were free to use as much time as they needed for these assignments. The verbatim transcripts of the activation task, the free recall and the pathophysiology protocols were segmented into propositions, applying a technique adapted from Frederiksen (1975). The number of propositions produced during activation of prior knowledge was counted. In addition, the number of propositions correctly recalled was recorded and the total number of propositions in the pathophysiology protocols established.

RESULTS

Figure 1 display the number of propositions produced by the students and the physicians while responding to the requirement to tell everything they remembered about endocarditis.

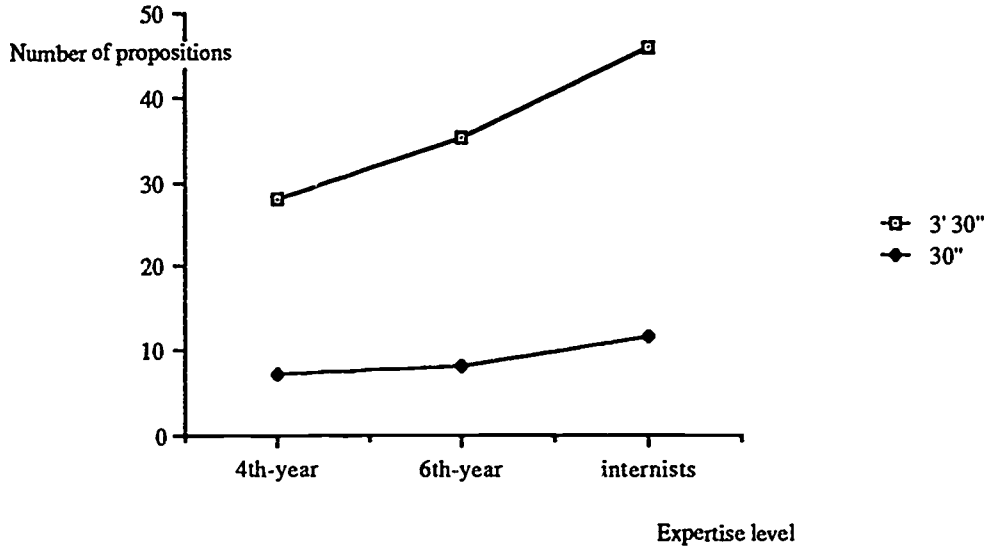

Figure 1. Average number of propositions produced in the activation task

As is to be expected, subjects were able to produce more propositions when entitled to talk about the subject for 3 minutes and 30 seconds as compared to only 30 seconds: $F (df= 56)= 93.67, p< .0001$. These data illustrate that the experimental manipulation was successful: The more time available, the more activation of prior knowledge took place. In addition, an effect of expertise is demonstrated: $F (df= 56)= 4.56, p< .01$; the internists generally produced more propositions in response to priming of prior knowledge than the students. Contrary to what Figure 1 suggests, no interaction effect was found: $F (df= 56)= 1.81, p< .17$.

Figure 2 shows the average number of propositions recalled from the endocarditis case which was subsequently presented to all subjects for 30 seconds.

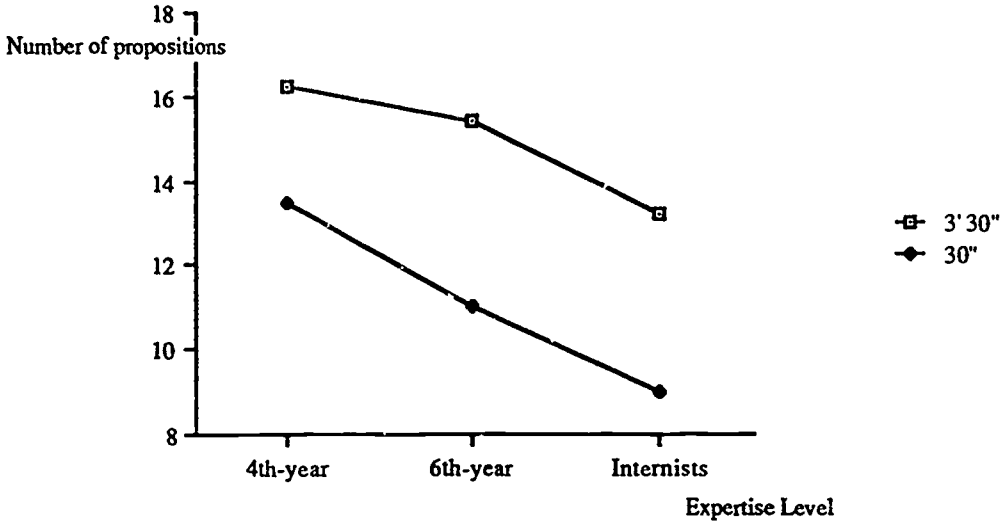

Figure 2. Average number of propositions recalled from the endocarditis case under two levels of priming

The recall data demonstrate both an effect of expertise: F (df= 56)= 2.61, p< . 08, and an effect of priming: F (df= 56)= 8.77, p< . 01. Generally, subjects of higher levels of expertise recall less information of the case than subjects of lower levels of expertise. And, although exposure time was equal for all groups, subjects who had less opportunity to activate relevant prior knowledge, recalled less from the endocarditis case

Figure 3 represents the average numbers of propositions produced by the subjects when asked to explain the signs and symptoms described in the case. Neither level of expertise, nor experimental manipulation had an effect on this variable: F (df= 56)= 1.74, p< .18 and F (df= 56)= . 05, p< .83 respectively.

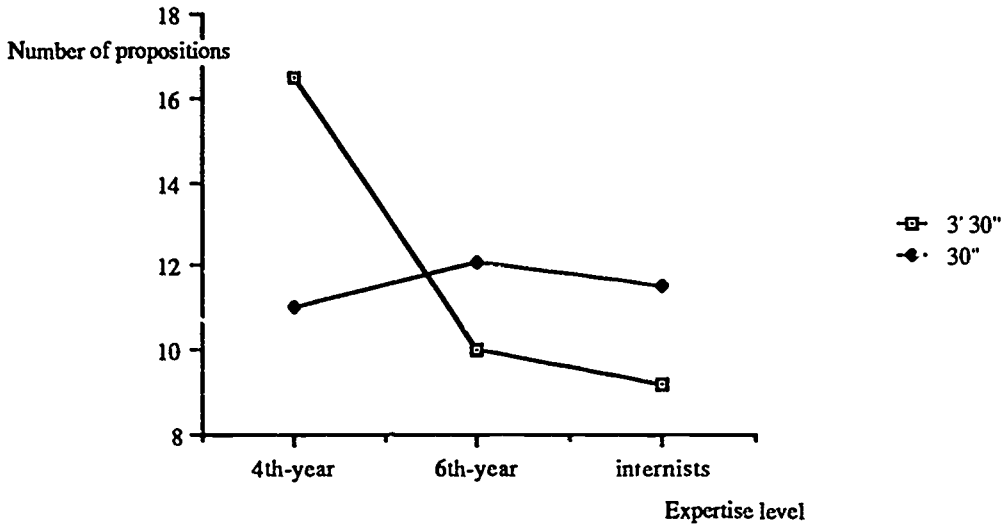

Figure 2. Average number of propositions produced in the post-hoc-explanation protocols under two levels of priming

DISCUSSION

In the discussion to follow, we will concentrate on the results of the activation task and the case recall task.

As indicated, the think-aloud task involving activation of prior knowledge of endocarditis, clearly shows an effect both of processing time and of expertise. The more time subjects have available, the more knowledge about the subject they are able to produce. In addition, the amount of prior knowledge produced is a function of level of expertise. The physicians produced more information than students when asked to tell everything they knew about endocarditis, suggesting that experts generally have more elaborate knowledge structures available for expertise related tasks.

According to current theories of text processing (e.g. Van Dijk and Kintsch, 1983), subsequent processing of the endocarditis case for 30 seconds would produce two recall phenomena; one related to time allowed for previous activation and one related to expertise. The first phenomenon would be that subjects who had more time available to activate relevant knowledge prior to case processing, would recall more information from the case than those who had less time. The data support this prediction: Subjects who only had 30 seconds to activate relevant knowledge prior to the case processing task, generally recall less than subjects who activated knowledge for 3

minutes and 30 seconds, indicating that endocarditis knowledge produced by the activation task was actually used in the comprehension of the case. Since less knowledge was activated under the short-activation condition, less comprehension and hence, less recall took place. This difference cannot be explained away by assuming activation differences while studying the text, since all groups had only 30 seconds to process the case information.

The second phenomenon to be expected would be related to expertise. Since experts have more knowledge, text processing theories predict more recall of a case relevant to that knowledge (Spilich, et al, 1979). Our data however, show exactly the opposite: Experts actually recall significantly less information from the case than the intermediates. Thus, even under conditions of conscious activation of pathophysiological knowledge, the intermediate effect emerges from the data.

This finding is in accordance with the notions put forward by Schmidt and Norman (1988). Schmidt and Norman assume that experts and intermediates apply different knowledge in the representation of a clinical case. In their view, the development of expertise in medicine progresses through several transitory stages, each of which is characterized by functionally different knowledge structures underlying performance. When applied to the understanding of clinical cases, these structures produce quite different effects. Novices, by their nature, have little more than a lay-person's idea of illness, because their knowledge is limited and mainly consists of an understanding of basic biological processes and structures, without much reference to the consequences of disease as exemplified in a clinical case. Students however, who enter residency, have already developed rich and elaborated causal networks explaining the signs and symptoms associated with a disease in terms of underlying pathophysiological processes, principles or mechanisms. Since by that time, their exposure to "real" patients still has been limited, they have to process informa tion extracted from a new case consciously and elaborately, reasoning through the causal pathophysiological networks available to them, in order to arrive at an understanding of that case. For experienced physicians however, causal pathophysiological knowledge has become compiled into diagnostic labels or simplified causal models explaining signs and symptoms, as a result of extensive use. Compiled knowledge is, by its nature, automatically and effortlessly activated by relevant cues in a case, because repeated activation in response to these same cues has caused its compilation (Anderson, 1985). However, Schmidt & Norman postulate that, in addition to the process of compilation, another process takes place as a result of frequent exposure to patients.

Experience adds something to the knowledge base of physicians that is only superficially taught in medical school but appears to be most relevant while diagnosing a patient: The constraints under which disease occurs in humans. To accommodate this point of view, Feltovich & Barrows (1984) have suggested that in the course of years of practice, physicians develop cognitive structures of various diseases which they call "illness scripts." These illness scripts contain the physician's idiosyncratic and compiled knowledge of the disease and its consequences, in addition to knowledge of the constraints under which a disease occurs. Illness scripts are frame— or list-like structures, containing prototypical information about a disease, which, when activated, guide a clinician through a case and support him in looking for cues that are relevant.

Thus, while students process a case non-automatically, applying unfolded pathophysiological knowledge, physicians automatically represent a case using an appropriate illness script[3]. Application of such different knowledge structures to the representation of a case produce different effects: Students recall many details of a case because the knowledge they apply is elaborate; physicians only remember cues directly related to the illness script applied. Students' recall is more extensive, but physicians' recall is more relevant (Coughlin and Patel, 1986).

CONCLUSION

The present study provides further evidence for processing differences between advanced medical students and experienced physicians in the representation of clinical cases. It demonstrates that recall performance of a case by these two groups is a function of at least two varables: The amount of processing of pathophysiological knowledge available in memory and the nature of the knowledge structure applied in the representation of the case. Amount of processing is causally responsible for the amount of recall, and differences in the nature of the knowledge structures applied explain the recall differences between intermediates and experts within the conditions of the experiment. The results generally support a stage theory on the development of expertise proposed by Schmidt and Norman (1988).

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[3] This conclusion is reached by applying the "modus tollens" principle: If physicians would use their pathophysiological knowledge of the case in the same way as the students, it would be incomprehensible why their recall is not better than students' recall, since the data displayed in Figure 1 demonstrate that they actually posses more knowledge of this kind than intermediates. Hence, they do not use this kind of knowledge in representing the case and must use something else.

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